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AGRICULTURAL MEMORANDUM NO. 927

Comparative frequency of low temperatures due to wind and radiation during spring in S E England

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Introduction

ADAS horticultural advisers have recently expressed concern at the apparent lack of information regarding the frequency of wind frosts in the South East of England. Hogg (1950) attempted to estimate the frequency of radiation and wind frosts ($\leq 0^{\circ}C$) during spring in Kent from daily observations of wind speed and minimum temperature at 0700 or 0900 GMT. He found that between 11 and 60% of all frosts during April (0-43% during May) were of wind origin, depending on site and proximity to the coast. Roe (1980) carried out a similar analysis for three stations in the S.E. using hourly observations of weather data at 0000 and 0600 GMT. These are shown in Table 1.

TABLE 1

Frequency of radiation and wind frosts ($\leq 0^{\circ}C$) during 1 April - 2 June

Station	Type of frost	Number of occasions	% Total
Gatwick (1959-78)	Radiation	121	96
	Wind	5	4
	Total	126	100
Manston (1961-78)	Radiation	23	74
	Wind	8	26
	Total	31	100
Abingdon (1959-78)	Radiation	76	84
	Wind	14	16
	Total	90	100

It was apparent from Roe's work that wind frosts were far less frequent than had previously been suggested by Hogg, probably because of the difficulty of extrapolating synoptic data (particularly wind) read at 0700 or 0900 GMT to the time of frost. This paper extends Roe's (1980) analysis using 24-hourly observations of weather data at six sites in the S.E. It is now thought that low temperatures (not necessarily frost) may reduce the activity of pollinating insects and prevent the fertilisation of the ova during the flowering period, although the critical temperature thresholds are unknown (Partis, private communication). For this reason temperatures $\leq 3^{\circ}C$ have been considered. Criteria for distinguishing between low temperatures, resulting from radiation and advection are also discussed.

Method

A program was written to extract hourly values of:-

i) dry-bulb temperature

ii) total cloud amount

TABLE 2

Frequency of low wind and radiative temperatures ($\leq 3^{\circ}C$) during spring

- Occasions due to a combination of wind and radiation are classified as LTW*

Station (period)	Type	Number of occasions		% Total		No. years with LTW/max possible		Mean No. of LTW in years with LTW		Max. No. of LTW in year		Years in 10 with LTW	
		April	May	April	May	April	May	April	May	April	May	April	May
Brize Norton (1973-79)	Rad.	54	22	79	92	4/7	2/7	3.5	1.0	7(1978)	1	5.7	2.9
	Wind.	14	2	21	8								
Gatwick (1971-79)	Rad.	89	55	87	99	6/9	1/9	2.2	1.0	6(1978)	1(1979)	6.6	1.1
	Wind	13	1	13	1								
Heathrow (1949-79)	Rad.	199	39	83	91	20/31	4/31	2.1	1.0	8(1958)	1	6.5	0.1
	Wind	41	4	17	9								
Hurn (1971-79)	Rad.	90	46	84	98	7/9	1/9	2.4	1.0	5(1975)	1(1971)	7.8	1.1
	Wind	17	1	16	2								
Manston (1971-79)	Rad.	39	10	72	83	6/9	1/9	2.5	2.0	5(1975)	2(1979)	6.7	1.1
	Wind	15	2	28	17								
Thorney Is. (1959-76)	Rad.	103	17	91	100	7/18	0/18	1.4	0.0	3(1964)	0	3.9	0.0
	Wind	10	0	9	0								

*LTW refers to a low temperature event of wind origin.

iii) mean wind speed at 10 m

iv) wind direction

and 3-hourly values of low cloud amount (when available) - for all hours with dry-bulb $\leq 3^{o}C$.

Low temperature events (ie. days with dry-bulb temperatures $\leq 3^{o}C$) were ascribed wind (hereafter denoted LTW) or radiation (LTR) using the following guidelines for a LTW:

i) 10 m mean hourly wind speed $\geq$ 7 knots (approx. 5 knots near to the surface).

ii) low cloud amount $>$ 4 oktas or total cloud amounts $>$ 6 oktas when not available.

iii) wind direction in the sector NW thro' N to E.

iv) small differences between screen and grass minimum temperature.

The criteria were applied subjectively and were supplemented by reference to first and last hours of frost and pattern of fall of dry-bulb temperature. DWR charts were used in ambiguous cases or when there was insufficient data. Winds have been restricted to the sector NW thro' N to E as these are often the coldest and most damaging although it is realised that winds from a southerly direction (eg France) can also be detrimental in certain synoptic situations. Six stations were considered - site details are presented in Appendix 1.

Results

The relative frequencies are shown in Table 2. It is apparent that between 1 and 3 in 10 of all occasions are of wind origin during April with a corresponding value of under 10% at most sites during May. The highest frequency of LTW occurs at Manston and is probably accentuated by its coastal location, being well exposed to cold winds from the near continent. The enhanced frequency at Brize Norton could be associated with a channelling of cold north-easterly winds down the west side of the Chilterns. The low proportion of LTW at Thorney Island is partly due to the omission of the years 1978/79 from the analysis when there were several occurrences recorded at other sites. Gatwick's location, however, within a frost hollow, favours the incidence of radiation rather than wind conditions.

The figures show that LTW can be expected, at least once, 6 or7 years in 10 during April and perhaps 1 year in 10 during May at most sites. An analysis of the duration of LTW for all six stations combined is shown in Table 3.

TABLE 3

Analysis of the duration (consecutive hours) of low advective temperatures ($\leq 3^{o}C$) for 6 stations combined.

Duration (hours)	Number of occasions	% of Total
$\leq$ 5	47	38
6 - 10	33	27
11 - 15	24	19
$\geq$ 16	20	16

Almost 40% of the occasions were of 5 or less consecutive hours duration while only 1/6th exceeded 16 hours.

Discussion

The term "wind frost" means different things to different people. The Americans, for example, associate a wind frost with a change of air mass trajectory during which the temperature falls progressively below 0°C whilst the pressure gradient is maintained or even increases (B.Ingham, private communication). Whilst such occasions are relatively common in the United States, they are rare to Britain during April and May.

In this country, wind frosts are classed as those events combining low temperature with wind, as happened on 25/26 April 1981 when plants were damaged. They occur typically during unstable northerly winds when the temperature and wind fluctuates as clouds alternate with clear intervals.

Many events occurred during this work which appeared to result from a combination of both radiative and advective influences and which could not be classified of one type. In fact the majority of LTW had some radiative element but, for simplicity, these have been considered to be of wind origin in Tables 2 and 3 with the view that combination events of this kind are likely to be more detrimental to crops than LTR alone. A typical example is shown in Appendix 2.

Sims (1975) suggested that ogives of frost frequency drawn for a particular site using data from a nearby long-term met. station should only be constructed from observations taken on radiation nights. Ogives of temperatures $\leq 3^{\circ}C$ on radiation nights during Spring (1 Apr - 2 Jun) were compared with similar curves drawn for all nights $\leq 3^{\circ}C$. Data for Gatwick and Manston, 1971-79, and Heathrow, 1959-79, revealed the curves to be similar. The error introduced in the radiation curve by including all nights was found to be less than 1 year in 10 at all temperature levels and is therefore unlikely to be significant.

In the past, the lack of hourly weather information has hindered workers from making assessments of the frequency of wind frosts at a particular site. Even with the recent advances in machinable data, the number of hourly stations in the South-east (with their relatively short periods of data when compared with the climatological stations) remains insufficient to build up a concise picture of wind frost frequency. An attempt was made to find criteria which would enable the origin of low temperature (wind or radiation) to be determined from readily available daily climatological data.

An objective definition of a radiation night was taken by Sims (1975) to be a night when the screen minimum temperature minus the grass minimum temperature ($=\Delta$) was 5 °F (2.8°C) or more. Of the elements considered (cloud, wind and dry bulb), inspection showed a value of $\Delta \leq 2^{\circ}C$ to be the best indicator of LTW and $\Delta > 2^{\circ}C$ for LTR.

In an investigation into the variations of grass-minimum depressions at several sites in England, Pickup (1980) found that on cloudy nights (ie nights with 8/8 low and or medium cloud at each available observation between 2100 and 0900 GMT - excluding nights with precipitation) with average overnight wind speeds in the range 5-10 knots, Δ was below 1°C. The choice of $\Delta = 2^{\circ}C$ as a critical threshold might correspond to the less stringent criterion employed for a LTW, which allows some element of radiation (low cloud > 4 oktas).

Good predictions are achieved in most circumstances using this criterion except in the case of a combination event. The proportion of low temperatures successfully predicted for thresholds $\leq 3^{\circ}C$ and $\leq 0^{\circ}C$ are shown in Table 4. Over 90% of all LTR and over 80% of all LTW were correctly ascribed at most sites, irrespective of the base temperature, although only 25-30% of the combination events were correctly predicted. Choosing temperatures $\leq 0^{\circ}C$ generally improves the results probably because the type of frost is more well defined with fewer combination events.

It is perhaps surprising that this method works at all in view of the fact that frost incidence at a particular site is largely dependent on local topography and site characteristics. Some factors which may affect the values of Δ are now discussed. One reason why $\Delta = 2^{\circ}C$ does not hold good for the combination event is that the

TABLE 4

Percentage of low temperature events accounted for using a critical value of $\Delta = 2.0^{\circ}C$

Station	Period	Radiation (Δ > 2.0°C)		Wind ($\Delta \leq$ 2.0°C)		Wind/Radiation ($\Delta \leq$ 2°C)	
		$\leq 3^{\circ}C$	$\leq 0^{\circ}C$	$\leq 3^{\circ}C$	$\leq 0^{\circ}C$	$\leq 3^{\circ}C$	$\leq 0^{\circ}C$
Brize Norton	1973-79	93	94	89	100	43	50
Gatwick	1971-79	93	92	67	-	-	-
Heathrow	1949-79	91	91	89	100	25	-
Hurn	1971-79	90	88	100	100	50	43
Manston	1971-79	96	100	88	75	-	-
Thorney Is.	1959-76	96	100	100	100	-	-

- No occasions

temperature can fall quickly in short clear periods in an otherwise cloudy night. Measurements of grass and air temperatures during Spring 1981 by Hough (private communication) showed that Δ could increase from 1-2°C to 4°C in the space of an hour, mainly due to a rapid fall in the grass minimum.

Snow cover may also accentuate Δ so that, for example, snow falling when the air temperature is 2 or 3°Cgives a grass minimum near 0°C and a value of Δ = 2 or 3°C on what would otherwise be a Δ = 0 or 1°C night. This would lead to an underestimate of LTW and is perhaps important during severe winters such as 1978/79 when there were comparatively many days of snowfall.

Soil type and moisture content at a particular site will also influence Δ. The largest values of Δ tend to occur over dry sandy soils and the smallest over moist clay soils. This might lead to an overestimate of the number of LTR over dry sandy soils and underestimate of LTR over moist clay soils.

Despite its obvious limitations (eg. the combination event), the use of Δ produces sufficiently good results on the whole at the sites selected for it to be used as a very simple indicator of frost type.

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Any comments or suggestions on this paper should be sent to the author.

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APPENDIX 1

BRIZE NORTON (NGR: 4292 2067) Effective anemometer height: 10 m.

Situated on the eastern flank of the Cotswolds in a vale with SW - NE orientation. Likely to be channelling of winds into NE and SW directions.

GATWICK (NGR: 5265 1407). Effective anemometer height: 10 m.

Situated in a frost hollow within the valley of the River Mole.

HEATHROW (NGR: 5077 1767) Effective anemometer height: 10 m.

Situated in a densely populated and reasonably flat plain surrounded by reservoirs to the South and West.

HURN (NGR: 4117 0978) Effective anemometer height: 11 m.

Frost hollow location between the River Stow and the River Avon.

MANSTON (NGR: 6335 1666) Effective anemometer height: 10 m.

Well exposed to winds from all directions with ground sloping away in all directions.

THORNEY ISLAND (NGR: 4761 1023) Effective anemometer height: 10 m.

Flat, coastal, location well exposed to southerly and south-easterly winds but sheltered to the north by the South Downs and to the south-west by the Isle of Wight.

APPENDIX 2

Example of a 'combination' event at Gatwick, 26 April 1971 ie. that due to a combination of both radiation and advection.

Hour (GMT)	Dry bulb(^{o}C)	Low Cloud (oktas)	Total Cloud	Mean hourly wind (kts)	No. hours with wind in the sector NW thro N to E
1200	2.7	8	8	11	1
1300	1.5		8	9	2
1400	1.6		8	9	3
1500	1.8	8	8	9	4
1600	2.0		8	10	5
1700	2.4		8	8	6
1800	3.0	8	8	8	7
1900	3.0		8	8	8
2000	2.8		8	6	9
2100	2.9	8	8	3	10
2200	2.4		8	3	10
2300	2.6		5	3	10
0000	1.4	1	1	3	10
0100	2.0		4	6	11
0200	1.1		3	6	12
0300	0.9	0	0	6	13
0400	0.1		0	5	14
0500	- 0.3		1	4	15
0600	0.1	1	1	3	16
0700	1.9		0	4	17

Advection conditions over period 1200 - 2000; radiation conditions over period 2300 - 0700.